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Influence of Spray-Solution Temperature and Holding Duration on Weed Control with Premixed Glyphosate and Dicamba Formulation

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Water is the primary carrier for herbicide application, and carrier-water–related factors can influence herbicide performance. In a greenhouse study, premixed formulation of glyphosate plus dicamba was mixed in deionized (DI) water at 5, 18, 31, 44, or 57 C and applied immediately. In a companion study, glyphosate and dicamba formulation was mixed in DI water at temperatures of 5, 22, 39, or 56 C and sprayed after the herbicide solution was left at the respective temperatures for 0, 6, or 24 h. In both studies, glyphosate plus dicamba was applied at 0.275 plus 0.137 kg ae ha^{-1} (low rate), and 0.55 plus 0.275 kg ha^{-1} (high rate), respectively, to giant ragweed, horseweed, Palmer amaranth, and pitted morningglory. Glyphosate plus dicamba applied at a low rate with solution temperature of 31 C provided 14% and 26% greater control of giant ragweed and pitted morningglory, respectively, compared to application at solution temperature of 5 C. At both rates of glyphosate and dicamba formulation, giant ragweed and pitted morningglory control was 15% or greater at solution temperature of 44 C compared to 5 C. Weed control was not affected with premixture of glyphosate and dicamba applied $\leq$ 24 h after mixing herbicide. When considering solution temperature, glyphosate and dicamba applied at low rate provided 13 and 6% greater control of Palmer amaranth and pitted morningglory, respectively, with solution temperature of 22 C compared to 5 C. Similarly, giant ragweed control was 8% greater with solution temperature of 39 C compared to 5 C. Glyphosate and dicamba applied at high rate provided 8% greater control of giant ragweed at solution temperature of 22 or 39 C compared to 5 C. Therefore, activity of premixed glyphosate and dicamba could be reduced with spray solution at lower temperature; however, the result is dependent on weed species.

Nomenclature: Dicamba; glyphosate; giant ragweed, *Ambrosia trifida* L. AMBTR; horseweed, *Conyza canadensis* (L.) Cronq. ERICA; Palmer amaranth, *Amaranthus palmeri* S. Wats. AMAPA; pitted morningglory, *Ipomoea lacunosa* L. IPOLA

Key words: Carrier water temperature, herbicide-mix holding duration, herbicide solution temperature, water quality.

El agua es el solvente primario para la aplicación de herbicidas, y factores relacionados a este solvente pueden influenciar el desempeño del herbicida. En un estudio de invernadero, una formulación con una premezcla de glyphosate más dicamba fue mezclada en agua desionizada (DI) a 5, 18, 31, 44, ó 57 C y aplicada inmediatamente. En un estudio acompañante, la formulación de glyphosate más dicamba fue mezclada en agua DI a temperaturas de 5, 22, 39, ó 56 C y aplicada después de que la solución del herbicida fue dejada en su respectiva temperatura por 0, 6, ó 24 h. En ambos estudios, glyphosate más dicamba fue aplicado a 0.275 más 0.137 kg ae ha^{-1} (dosis baja), y 0.55 más 0.275 kg ha^{-1} (dosis alta), respectivamente, a *Ambrosia trifida*, *Conyza canadensis*, *Amaranthus palmeri*, e *Ipomoea lacunosa*. Glyphosate más dicamba aplicados a la dosis baja con una temperatura de solución de 31 C brindaron 14 y 26% más de control de *A. trifida* e *I. lacunosa*, respectivamente, al compararse con la aplicación con una temperatura de solución de 5 C. A ambas dosis de la formulación de glyphosate y dicamba, el control de *A. trifida* e *I. lacunosa* fue $\geq$15% con una temperatura de solución de 44 C al compararse con 5 C. El control de malezas no fue afectado con la premezcla de glyphosate y dicamba aplicada $\leq$ 24 h después de la mezcla del herbicida. Cuando se consideró la temperatura de la solución, glyphosate y dicamba aplicados a la dosis baja brindaron 13 y 6% mayor control de *A. palmeri* e *I. lacunosa*, respectivamente, con la temperatura de solución de 22 C al compararse con la de 5 C. Similarmente, el control de *A. trifida* fue 8% mayor con la temperatura de solución de 39 C comparada con 5 C. Glyphosate y dicamba aplicados a la dosis alta brindaron un control 8% mayor de *A. trifida* con temperaturas de solución de 22 ó 39 C comparados a 5 C. Así, la actividad de la premezcla de glyphosate y dicamba podría ser influenciada por temperaturas bajas de la solución de aspersión. Sin embargo, el resultado depende de la especie.

Water is the predominant carrier for most of the herbicide applications. Carrier water quality, which is determined by hardness, pH, and turbidity, varies depending upon the geographical locations and surface- and groundwater sources. With this variation in carrier water quality, herbicide perfor-

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mance can be impacted (Nalewaja and Matysiak 1991; Stahlman and Phillips 1979). Further studies have reported the effects of water hardness, pH, and turbidity on herbicide performance for weed control (Buhler and Burnside 1983; Green and Hale 2005; Ramsdale et al. 2003). Therefore, carrier water without hardness cations, at appropriate pH levels, and applied at suitable volumes, are important considerations for herbicide performance. Additionally, spray-solution temperature may possibly be another water quality component to consider for herbicide application.

Herbicides are sprayed at different times of the year, from early spring through late fall, so spray-solution temperature is variable depending on weather. Herbicide carrier water is often stored in a tank where water equilibrates to ambient air temperature. Therefore, herbicides are applied at lower spray-solution temperature during early-spring and late-fall applications and warmer spray-solution temperature during late spring and summer months. Currently, knowledge on the herbicide performance at different solution temperatures and holding duration is limited, and this might, under certain circumstances, compromise weed control efficacy. Water temperatures can range from about 10 C during early spring to 50 C during summer (William G. Johnson, personal observation). According to Beltran et al. (2000), the rate of isoxaflutole degradation is greatly influenced by solution temperature, and rate of degradation was higher at 50 C compared to 22 C solution temperature. Likewise, the activity of aquatic herbicides such as diquat and endothal on curly-leaf pondweed (*Potamogeton crispus* L.) varied with change in water temperature (Netherland et al. 2000). Researchers reported that curly-leaf pondweed control was reduced with herbicide application at water temperature of $<$ 18 C compared to 25 C.

Herbicide applications are often temporarily postponed and herbicide solution is stored in the sprayer tank because of unfavorable weather conditions occurring after mixing herbicide. Moreover, duration for storing spray solution could range from hours to days when waiting for suitable spray conditions. Postponing of application during high wind speed and potential rainfall is helpful in preventing herbicide drift and washing off of applied herbicide (Ellis and Griffin 2002). A study by Beltran et al. (2000) illustrated that solution temperature affected the persistence of isoxaflutole herbicide. Moreover, hydrolysis of isoxaflutole herbicide occurs in the aqueous solution (Lin et al. 2002). Ramezani et al. (2008) also reported that herbicides from imidazolinone family break down naturally over time during storage in the spray solution.

A new, less volatile formulation of dicamba has been developed and is being premixed with glyphosate for use in dicamba-resistant crops. Dicamba-resistant crops are awaiting regulatory approval and are expected to be commercially available in the near future. In order to maximize effectiveness from glyphosate and dicamba formulations application, there is a need to determine the effects of water quality on performance of the herbicide premixture. As herbicides are applied under a wide range of spray-solution temperatures, studies evaluating the effect of spray-solution temperature may be helpful in preventing adverse effects on herbicide efficacy. Additionally, this knowledge may lead to the new recommendations for mixing and applying herbicides with respect to spray-solution temperature. The primary objective of this research was to evaluate the effect of spray-solution temperature and holding duration on a premixture of glyphosate and dicamba. Studies were conducted with the hypothesis that low and high spray-solution temperature, and prolonged holding of spray solution, will reduce the activity of premixed glyphosate plus dicamba.

Materials and Methods

Greenhouse studies were conducted in spring and fall of 2013 to evaluate (1) the effect of spray-solution temperature, and (2) the effect of spray-solution temperature and holding duration on activity of a premixed formulation of glyphosate and dicamba formulation (MON 76757: Monsanto Company, St. Louis, MO). MON 76757 consisted of monoethanolamine (MEA) salt of glyphosate (37.94%), diglycolamine (DGA) salt of dicamba (18.82%), surfactant ($\leq$ 3%), and formulating ingredients ($\leq$ 40.24%). In both studies, giant ragweed, horseweed, Palmer amaranth, and pitted morningglory were used as bioassay species.

In the greenhouse, giant ragweed, horseweed, Palmer amaranth, and pitted morningglory seeds

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were planted for germination on 26 by 26 by 6 cm^3 poly flats in potting soil (Redi-Mix, Sun-Gro Redi-Earth Plug and Seedling Mix, Sun-Gro Horticulture, Bellevue, WA). Seedlings at one to two true-leaf stage were transplanted into 164-cm^3 cone containers (Ray Leach SC-10 Super Cell Cone-tainers, Stuewe & Sons, Tangent, OR) filled with potting soil. Transplants were watered daily and fertilized weekly (Miracle-Gro® Water Soluble All Purpose Plant Food [24–8–16], Scotts Miracle-Gro Products Inc., Marysville, OH). Minimum and maximum temperatures in the greenhouse were maintained at 25 to 28 C, and plants were grown under a 14-h photoperiod regiment.

Study 1: Effect of Spray-Solution Temperature. Carrier water temperatures were maintained at 5, 18, 31, 44, or 57 C, and herbicide was added at these water temperatures. Water temperature of 5 C was maintained by storing water in a refrigerator that was preset at required temperature. Cold water was added to water at room temperature (22 C) to achieve water temperature of 18 C. Water was heated in a beaker on a heating plate to maintain temperature of 31 or 44 C. Likewise, water temperature at 57 C was maintained by heating water in a hot water bath. Water maintained at different temperatures was transported to spray chambers in a heat-insulated and sealed container to prevent fluctuation in spray-water temperatures. The herbicide premixture was mixed in water set at appropriate temperatures and sprayed immediately after mixing. Premixed formulation of glyphosate and dicamba was applied at two rates: low, 0.275 plus 0.137; and high, 0.55 plus 0.275 kg ae ha^{-1}.

Study 2: Effect of Spray-Solution Temperature and Holding Duration. In this study, treatments consisted of two factor combinations: (1) spray-solution temperature and (2) spray-solution holding duration. Herbicide was mixed in water maintained at either 5, 22, 39, or 56 C; and herbicide solutions were stored for either 0, 6, or 24 h at the above-mentioned temperatures. Water temperatures were maintained as mentioned in study 1. Herbicide was mixed 24 and 6 h prior to the application in order to maintain respective spray-solution holding duration, but was mixed and sprayed immediately after mixing for 0-h holding duration. Premixed formulation of glyphosate and dicamba was applied at 0.275 plus 0.137; and 0.55 plus 0.275 kg ae ha^{-1} illustrating low and high rates, respectively.

Treatments for both studies were applied at 6- to 8-cm rosette diam of horseweed, 5- to 6-leaf stage of giant ragweed and pitted morningglory, and 8- to 12-leaf stage of Palmer amaranth. Treatments were applied with the use of a compressed air track sprayer calibrated to deliver 140 L ha^{-1} with a TeeJet 8002EVS nozzle (TeeJet Technologies, Spraying Systems Co.), at a spraying speed of 4.8 km h^{-1}. In order to avoid herbicide antagonism with carrier water pH or hardness, deionized (DI) water was used for mixing herbicide. Both the studies were conducted as a randomized complete block design with four replications, and repeated another time for two experiment runs.

Data Collection and Analysis. Plants were evaluated for 3 wk following treatment application. Visually assessed percent control was recorded on a 0 to 100 scale (where 0 is equals to no injury or similar to nontreated plant and 100 is equal to complete death of plant) at weekly intervals for 3 wk. Percent control data were recorded based on the symptoms such as yellowing, twisting, curling, and callusing of treated plants compared to nontreated plants. Three weeks after treatment (WAT) plants were harvested above the soil surface and were placed in a 60 C forced-air drier for 1 wk. Dried plant shoot was weighed for dry weight data. Dry weight of each treatment was subtracted from dry weight of untreated control, and converted to the dry weight reduction percent compared to untreated control.

Data were subjected to ANOVA with the use of PROC GLM in SAS version 9.3 (SAS Institute Inc., Cary, NC 27513). In both studies, each weed species were analyzed separately. Data were tested for assumptions of ANOVA by confirming that residuals were random, homogeneous, and followed normality. Data from the spray-solution temperature study did not require transformation. However, giant ragweed, Palmer amaranth, and pitted morningglory percent control and dry weight reduction percent from spray-solution temperature and holding duration study required arcsine transformations. In both studies, there was no significant difference ($\alpha \leq 0.05$) between experimental runs; therefore, data were pooled over experimental run for the analysis. Treatment means were separated with the use of adjusted Tukey at

Table 1. Percent control and dry weight reduction percent of giant ragweed, horseweed, Palmer amaranth, and pitted morningglory with premixed glyphosate and dicamba applied at 0.275 plus 0.137 kg ha^{-1}, respectively, as affected by spray-solution temperature at 3 wk after treatment (WAT).[a]

	Giant ragweed		Horseweed		Palmer amaranth		Pitted morningglory	
Spray-solution temperature	Control[b]	Dry-weight reduction[c]	Control	Dry-weight reduction	Control	Dry-weight reduction	Control	Dry-weight reduction
C	%							
5	61 b	31 a	63 a	21 a	82 a	49 a	72 b	33 a
18	64 ab	29 a	66 a	29 a	89 a	22 a	81 ab	38 a
31	75 a	39 a	65 a	27 a	81 a	33 a	98 a	44 a
44	76 a	30 a	64 a	23 a	76 a	36 a	92 ab	44 a
57	69 ab	40 a	65 a	29 a	80 a	58 a	80 ab	40 a

[a] Data were pooled over two experimental runs for the analysis.

[b] Means within a column followed by the same letter are not different based on adjusted Tukey at $\alpha = 0.05$.

[c] Dry weight reduction percent was calculated by subtracting dry weight of each temperature from untreated control and converting it to percent of untreated control. Mean dry weights for untreated giant ragweed, horseweed, Palmer amaranth, and pitted morningglory were 0.8, 0.56, 0.45, and 0.48 g $plant^{-1}$, respectively.

$P \leq 0.05$. For analysis, mean separation was based on the arcsine transformed data, but back-transformed data were presented for reporting results. Likewise, percent control data were recorded for 1 through 3 WAT; however, data were presented from 3 WAT because of similar weed control trends.

Results and Discussion

Effect of Spray-Solution Temperature. Premixed formulation of glyphosate and dicamba applied at 0.275 plus 0.137 kg ae ha^{-1} and at spray-solution temperature of 5 C reduced giant ragweed control to 61% compared to 75 or 76% when the spray solution was mixed in water at temperatures of 31 or 44 C, respectively (Table 1). Similarly, there was a difference in pitted morningglory control from glyphosate and dicamba applied at spray-solution temperature of 5 C compared to 31 C. Glyphosate and dicamba provided 72% control of pitted morningglory at spray-solution temperature of 5 C compared to 98% control at spray-solution temperature of 31 C. However, spray-solution temperature had no observed effect on premixed glyphosate and dicamba for horseweed and Palmer amaranth control.

Effect of spray-solution temperature on premixed glyphosate and dicamba applied at 0.55 plus 0.275 kg ha^{-1} was similar to the results observed with 0.275 plus 0.137 kg ha^{-1}. Giant ragweed and pitted morningglory control from the premixture of glyphosate and dicamba at 0.55 plus 0.275 kg ha^{-1} was reduced by low spray-solution temperature (Table 2). Giant ragweed control was 20% higher from herbicide applied at spray-solution temperature of 31 C compared to 5 C. Likewise, pitted morningglory control increased at least 20% when glyphosate and dicamba formulation was applied at spray-solution temperature of 44 or 57 C compared to 5 C. Similar to the observation with low rate, there was no effect of spray-solution temperature on high rate of premixed glyphosate and dicamba on horseweed and Palmer amaranth.

Percent control of giant ragweed and pitted morningglory was reduced with low spray-solution temperature when premixed glyphosate and dicamba was applied at low and high rates. In the current study, the result observed with percent control data did not corresponded to the giant ragweed and pitted morningglory dry-weight reduction percent (Tables 1 and 2). The reason for this observation might be that sublethal rates of growth regulator herbicides can induce growth of callus tissue on treated plants, resulting in increased biomass. Other researchers have reported similar issues with callus growth and its influence on dry weight when evaluating growth-regulator herbicides (Dowler 1969; Roskamp et al. 2013). Enloe et al. (1999) reported negative correlation between percent control and biomass in a study evaluating field bindweed (*Convolvulus arvensis* L.) control with quinclorac and 2,4-D. In all the studies mentioned

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Table 2. Percent control and dry weight reduction percent of giant ragweed, horseweed, Palmer amaranth, and pitted morningglory with premixed glyphosate and dicamba applied at 0.55 plus 0.275 kg ha^{-1}, respectively, as affected by spray-solution temperature at 3 wk after treatment (WAT).[a]

	Giant ragweed		Horseweed		Palmer amaranth		Pitted morningglory	
Spray-solution temperature	Control[b]	Dry-weight reduction[c]	Control	Dry-weight reduction	Control	Dry-weight reduction	Control	Dry-weight reduction
C	%							
5	66 b	40 a	73 a	36 a	86 a	65 a	74 b	41 a
18	79 ab	37 a	79 a	41 a	92 a	63 a	89 ab	49 a
31	86 a	35 a	74 a	34 a	95 a	60 a	86 ab	47 a
44	78 ab	41 a	79 a	39 a	96 a	60 a	94 a	55 a
57	74 ab	44 a	80 a	39 a	90 a	63 a	95 a	47 a

[a] Data were pooled over two experimental run for the analysis.

[b] Means within a column followed by the same letter are not different based on adjusted Tukey at $\alpha = 0.05$.

[c] Dry-weight reduction percent was calculated by subtracting dry weight of each temperature from untreated control and converting it to percent of untreated control. Mean dry weights for untreated giant ragweed, horseweed, Palmer amaranth, and pitted morningglory were 0.78, 0.59, 0.48, and 0.49 g plant^{-1}, respectively.

above, authors have illustrated results with emphasis on visually assessed percent control data.

Effect of Spray-Solution Temperature and Holding Duration. There was no interaction of spray-solution temperature and holding duration on any of the four weed species evaluated in this study. Similarly, data pooled over experimental run and spray-solution temperature illustrated that there was no effect of holding duration on efficacy of premixed glyphosate and dicamba for giant ragweed, horseweed, Palmer amaranth, and pitted morningglory control (data not shown). These results are consistent with those reported previously by Stewart et al. (2009). Authors reported that efficacy of POST-applied glyphosate or dicamba was not affected by herbicide solution left for 0, 1, 3, or 7 d after mixing, for velvetleaf (*Abutilon theophrasti* Medik.), redroot pigweed (*Amaranthus retroflexus* L.), common ragweed (*Ambrosia artemisiifolia* L.), and common lambsquarters (*Chenopodium album* L.) control.

The data averaged across experimental run and spray-solution holding duration illustrated that there was a difference between low spray-solution temperature (5 C) compared to medium spray-solution temperatures (22 or 39 C) for activity of premixed glyphosate and dicamba applied at 0.275 plus 0.137 kg ha^{-1} (Table 3). The difference was observed for giant ragweed, Palmer amaranth, and pitted morningglory control. Giant ragweed control was reduced 8% with premixture of glyphosate and dicamba applied at spray-solution temperature of 5 C compared to 39C. Similarly, Palmer amaranth control was reduced 13%, with glyphosate and dicamba formulation applied at spray-solution temperature of 5 C compared to 22 C. Results observed with visually accessed control rating also corresponded with Palmer amaranth dry weight reduction percent. Palmer amaranth biomass reduction was greater when glyphosate and dicamba was applied at 22 C compared to 5 C. Spray-solution temperature of 5 and 56 C negatively influenced pitted morningglory control compared to 22 C for glyphosate and dicamba application. Glyphosate and dicamba control of pitted morningglory was reduced 6 or 7% from temperature extremes evaluated in this study (5 or 56 C) compared to 22 C. In contrast, there was no effect of spray-solution temperature on activity of premixed glyphosate and dicamba for horseweed control.

Glyphosate and dicamba at 0.55 and 0.275 kg ha^{-1} had a reduced effect on giant ragweed when applied with lower solution temperature (Table 4). Giant ragweed control was at least 8% higher at spray-solution temperatures of 22 or 39 C compared to 5 C. Unlike the results observed with low rate of glyphosate and dicamba formulation (Table 3), there was no effect of spray-solution temperature on Palmer amaranth and pitted morningglory control with application made at high rate (Table 4). This result could be attributed to the compensation of effect of spray-solution temperature on

Table 3. Percent control and dry-weight reduction percent of giant ragweed, horseweed, Palmer amaranth, and pitted morningglory with premixed glyphosate and dicamba applied at 0.275 plus 0.137 kg ha^{-1}, respectively, as affected by spray-solution temperature at 3 wk after treatment (WAT). Data were pooled over experiment run and solution holding duration.

	Giant ragweed		Horseweed		Palmer amaranth		Pitted morningglory	
Spray-solution temperature	Control[a,b]	Dry-weight reduction[c]	Control	Dry-weight reduction	Control	Dry-weight reduction	Control	Dry-weight reduction
C	%							
5	57 b	24 a	61 a	16 a	60 b	26 a	45 b	14 a
22	62 ab	25 a	60 a	13 a	73 a	54 b	51 a	14 a
39	65 a	27 a	59 a	8 a	62 ab	31 a	47 ab	13 a
56	62 ab	27 a	60 a	13 a	66 ab	44 ab	44 b	3 a

[a] Means within a column followed by the same letter are not different based on adjusted Tukey at $\alpha = 0.05$.

[b] Mean separation on giant ragweed and pitted morningglory percent control and dry-weight data are based on arcsine and $\log_{10}$ transformations, respectively.

[c] Dry-weight reduction percent was calculated by subtracting dry weight of each temperature from untreated control and converting it to percent of untreated control. Mean dry weights for untreated giant ragweed, horseweed, Palmer amaranth, and pitted morningglory were 1.58, 1.66, 1.51, and 1.01 g plant^{-1}, respectively.

glyphosate and dicamba formulation with the increased rate of herbicides. Nalewaja and Matysiak (1991) reported that glyphosate applied at a high rate overcame the effect of carrier water salts observed with glyphosate applied at low rate. Similarly, the effect of environmental factors such as soil moisture, irradiance, relative humidity, and temperature on glyphosate efficacy was mitigated with increased herbicide rate (Adkins et al. 1998).

Lower temperature (5 C) of spray-solution negatively influenced the efficacy of premixed glyphosate and dicamba formulation for giant ragweed and pitted morningglory control in both studies, and Palmer amaranth control with low rate in one of the study. However, horseweed control was not affected in either study with premixture of glyphosate and dicamba applied at different spray-solution temperatures. This result illustrates that effect of spray-solution temperature on premix formulations of glyphosate and dicamba efficacy could vary with weed species and herbicide rate. Previous studies have shown that spray water quality impact on herbicide efficacy is dependent on weed species. Roskamp et al. (2013) reported that 2,4-D applied with DI water and water consisting of calcium cations provided 85 and 9% control of

Table 4. Percent control and dry-weight reduction percent of giant ragweed, horseweed, Palmer amaranth, and pitted morningglory with premixed glyphosate and dicamba applied at 0.55 plus 0.275 kg ha^{-1}, respectively, as affected by spray-solution temperature at 3 wk after treatment (WAT). Data were pooled over experiment run and solution holding duration.

	Giant ragweed		Horseweed		Palmer amaranth		Pitted morningglory	
Spray-solution temperature	Control[a,b]	Dry-weight reduction[c]	Control	Dry-weight reduction	Control	Dry-weight reduction	Control	Dry-weight reduction
C	%							
5	63 b	22 a	72 a	29 a	92 a	66 a	58 a	13 a
22	71 a	22 a	72 a	25 a	93 a	67 a	57 a	17 a
39	72 a	23 a	71 a	26 a	90 a	64 a	59 a	15 a
56	68 ab	17 a	73 a	28 a	89 a	64 a	58 a	18 a

[a] Means within a column followed by the same letter are not different based on adjusted Tukey at $\alpha = 0.05$.

[b] Mean separation on giant ragweed and Palmer amaranth percent control and dry-weight data are based on arcsine and $\log_{10}$ transformations, respectively.

[c] Dry-weight reduction percent was calculated by subtracting dry weight of each temperature from untreated control and converting it to percent of untreated control. Mean dry weights for untreated control of giant ragweed, horseweed, Palmer amaranth, and pitted morningglory were 1.34, 1.67, 1.54, and 1.03 g plant^{-1}, respectively.

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common lambsquarters, respectively; however, there was no difference on horseweed control with those treatments. Likewise, Pline et al. (1999) and Nalewaja and Matysiak (1992) have reported variable response of weed species to adjuvants used with herbicides in order to overcome salt antagonism present in spray water.

This research suggests that if the spray conditions are not appropriate after mixing premixed glyphosate and dicamba formulation with spray water, delaying spray application up to 24 h does not compromise herbicide activity. Spray-solution temperature at 5 C showed that relatively cold water reduced the efficacy of premixed glyphosate and dicamba for giant ragweed and pitted morningglory control. However, efficacy of premixed glyphosate and dicamba was not compromised when applied at spray-solution temperature of $\geq$ 18 and $\leq$ 44 C. Therefore, during early-spring or late-fall application, when spray water is stored in aboveground tanks at low air temperature, precautions should be taken to adjust herbicide spray water at 18 C or above for achieving maximum weed control from premixed glyphosate and dicamba formulation.

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